NOTES ON THE RIVERS OF SACRAMENTO AND LOWER SAN JOAQUIN WATERSHEDS DURING THE MONTH OF JULY, 1913.

By N. R. TAYLOR, Local Forecaster.

Sacramento watershed.—The rivers in this watershed were generally lower than during any July of which there is a record. In the upper reaches of the Sacramento itself the river averaged slightly above the low water of 1910. From Colusa, however, southward to Walnut Grove the Sacramento averaged from 0.1 of a foot to nearly a foot below all previous low-water stages of which there is a record or a remembrance. At Sacramento City on the 23d the river reached a stage of 4 feet, which is the lowest ever reached in any month of which there is an authentic record.

While there were some heavy rains in the high regions of the Sierra Nevada during the month there was little effect noted in the run-off of the main western feeders or of the trunk stream, the greatest 24-hour rise observed being 0.8 of a foot in the American River.

Tides were common in the Sacramento River during the entire month and were felt for several miles above the mouth of the American. In one instance there was a tide of 1.4 feet in the river at Sacramento City.

Many sand bars have been uncovered during the present low water and, in some cases, channels have changed, making navigation difficult. During the extreme low water the steamer *Empress* struck bottom opposite the city wharf at Sacramento and was unable to reach her berth.

Steamboat men are complaining about the amount of water now being taken out of the river for irrigation purposes, and claim that between 60 and 70 pumps, with capacities ranging from 6 to 12 inch intake, are constantly at work in the Sacramento between the mouth of the American and that of the Feather.

San Joaquin watershed.—The Tuolumne River, while unusually low for the month, averaged about 0.9 of a foot above that of July, 1910. In all other streams the water was the lowest of any July since records have been kept. This was especially so of the Calaveras, which was practically dry during the entire month, and the lower San Joaquin, which averaged between 6 and 7 feet below the July normal and nearly a foot below the previous low water stage, which was in 1910.

FORECASTING THE WATER SUPPLY IN CALIFORNIA.

(From Weather Bureau records of precipitation.)

By Prof. ALEXANDER G. MCADIE.

The writer has in press a somewhat extensive memoir on the "Rainfall of California." [1] From the various records available it appears that no secular periodicity of wet and dry seasons can be found and that excessive rainfalls, also periods of prolonged drought, come and go irregularly. It also appears that there are certain definite relations between excess and deficiency in rainfall and the distribution of atmospheric pressure. Thus the character of a month, and sometimes of a season, is found to bear a direct relation to the position and intensity of certain pressure areas, which for lack of a better name have been called centers of action. This term we believe was originally used by de Bort and has been lately abbreviated by continental writers to action centers. As the term is somewhat awkward and lacks precision, the writer suggests the use of the term hyperbar for abnormally high seasonal pressure over a given district, and infrabar for a well-marked seasonal depression. The terms pleiobar and meiobar have been suggested by M. A. F. Prestel, but do not seem to be altogether appropriate.

A good illustration of this law of seasonal variation of precipitation and aberration of hyperbars and infrabars is found in the months of January and February, 1902. January, usually a wet month, was abnormally dry, the deficiency in precipitation for California determined by records from nearly 200 stations was approximately 33,000,000 acre-feet. This was a dry winter month and there was every prospect of a shortage of water for the following spring and summer. But what happened? There was a marked change in the position and intensity of the Aleutian low (the infrabar) and also in the location of the continental high (the hyperbar) with the result that February was abnormally wet and even in the short month there was an excess of practically 43,000,000 acre-feet.

The following table gives the approximate precipitation for California in million acre-feet:

	January.	February.	March.	Winter.
1897	22	49	33	104
1898	9	24	6	39
1899	29	4	51	84
1900	28	8	19	55
1901	42	50	9	101
1902	12	68	29	109
1903	38	15	48	101
1904	12	66	71	149
1905	36	35	45	116
1906	66	42	77	185
1907	63	38	89	190
1908	39	36	12	87
1909	135	67	28	230
1910	40	20	20	80
1911	110	29	50	189
1912	28	6	43	77
1913	42	17	18	77
	751	574	648	1,973
Mean	44	34	38	116

Attention is called to the winter of 1909, particularly January, when nearly three times the average amount of rain fell. As early as the end of January, notwithstanding floods, excessive runoff, and general waste, it was plain that there would be an abundance of water. Reference to the depth of snow on the ground shows how deep the snow cover was.

The present season (1913) is especially interesting because while January was a month of nearly average water supply, February and March gave only about half the normal precipitation. The amount of water which has fallen as rain is not sufficient for general need and must be supplemented from storage or ground sources.

The depth and extent of the snow cover in the mountains give in a general way a reliable index of the character of the season, the probable water supply, and the river stages. This frozen storage decreases in four ways: First, by melting or run-off; second, by evaporation; third, by percolation or seepage; and fourth, by absorption of forest cover. This water of vegetation in part is reevaporated from the leaf surface by the processes of transpiration; but so far as California is concerned the water is practically lost.

Of these four factors, the second, that is, evaporation, is as effective in dissipating snow as any of the others. There are certain thermodynamic reasons why a current of air in these latitudes moving east from sea level over

[1] To be published by the University of California.

the Coast Range and the Sierra Nevada should lose its load of water vapor in this passage, gaining heat in descending the eastern slope and becoming in effect a desiccating wind of the type of the chinook, foehn, or familiar norther. Such winds are not infrequent in California and some observations show that under such conditions the depth of snow is rapidly decreased, exceeding the normal rate of decrease for a still day, 300 per cent.

After the middle of March the first factor, or ordinary melting, becomes effective. In various publications the writer has discussed the normal rate of melting and given diagrams for comparing rates and seasons, so that the probable date of disappearance of the snow may be determined.

The third and fourth factors are troublesome and uncertain. The writer is of opinion that none of the present forms of measuring devices give reliable records for determining the seepage and the water of vegetation. In his opinion it will be necessary to employ seepage tanks or seasonal snow gages so arranged in the ground as to measure approximately the water of percolation.

In a rough way stream-flow measurements may be utilized for determining what percentage of the total depth of snow on the ground disappears to reappear in the form of run-off. For this purpose I have taken the only available gaging station in the watershed of the American River, Fairoaks (see Water-Supply Paper No. 298, U. S. Geological Survey), and compared the snow depth, the total precipitation at Summit, and the monthly run-off. The total precipitation is a truer measure of run-off than depth of snow, because of the reasons given above and in addition, the fact that the water content of the snow is and must always be an uncertain quantity, depending upon the age of the snow bank, the action of the wind in packing, the character of the mountain slope with regard to timber and brush, the temperature factor, and the original condition of congelation. The writer had once to deal with a snow bank at Summit 12 feet deep. No snow sampler or density gage measurements as ordinarily made would reliably give the water contents. Fortunately there were tunnels in the snow and samples could be obtained for the entire depth. Twenty inches of snow from the top of the pack when melted made 1 inch of water. Four inches of snow from the bottom of the pack when melted made 1 inch of water.

TOTAL PRECIPITATION AT SUMMIT.

	January.	February.	March.	Season.
	Inches.	*Inches.*	*Inches.*	*Inches.*
1907	13.50	4.38	27.36	45.24
1908	3.50	4.50	10.20	18.20
1909	29.44	8.94	4.60	42.98
1910	8.60	5.10	4.98	18.68
1911	28.90	5.30	10.63	44.83
1912	7.00	.46	6.10	13.56
1913	13.60	2.05	3.20	18.85

ESTIMATED RUN-OFF IN ACRE-FEET.

	January.	February.	March.	Season.
1907	255,000	822,000	1,520,000	2,597,000
1908	160,000	113,000	202,000	475,000
1909	1,490,000	861,000	397,000	2,748,000
1910	524,000	291,000	646,000	1,461,000
1911	855,000	589,000	799,000	2,243,000
1912	68,200	44,800	118,000	231,000
1913	....	....	....	....

Attention is called to the amount of precipitation for the two seasons, 1912 and 1913, from which it is evident that the run-off must be small. The seasons of 1907, 1909, and 1911 indicate ample water and run-offs far above the normal.

The following notes are of interest in a general way in connection with the character of the precipitation:

February, 1907, snow very wet.

March, 1907, snow abnormally heavy.

January, 1908, a marked decrease in precipitation at levels above 3,000 feet.

January, 1909, abnormally heavy rain and snow. Also heavy run-off, possibly due to saturated condition of ground.

January, 1911, unusually heavy precipitation, but run-off light. Notwithstanding the fact that more rain fell in the drainage basin of the Sacramento Valley than during any previous January, the water courses were much below the normal. The explanation of this is that the rains were mostly in the nature of warm showers. There was less precipitation in the mountain sections than at sea level. Moreover, the precipitation in the mountain sections did not equal that of January, 1909.

One interesting and new feature comes out of this discussion, namely, that in certain storms in California there is not the usual increase in amount of precipitation with elevation; but on the contrary a maximum rate prevails below the 1,000-meter level. Ordinarily the precipitation increases with elevation up to nearly the 2-kilometer level. This is of some importance in connection with the selection of reservoirs.